

Appendix A Addendum

This Appendix provides an update to the report describing additional development work and progress in solving technical problems with the Energy Shaver through year 2002. The Energy Shaver is now called the Therma-Stor Cooling Booster.

Overview

The Therma-stor Cooling Booster (TCB) improves the thermodynamic efficiency of an air conditioner by lowering its effective heat rejection temperature. The TCB uses a thermal energy storage medium to provide a colder-than-ambient heat sink during the day. The energy stored during the day is rejected to the cool night air, thereby completing the heat transfer cycle. The TCB is a patented thermal energy storage device designed specifically for small air conditioners. It is a simple, low cost device that is retrofitted to OEM commercial and residential air conditioners to create a highly efficient condensing unit.

The Therma-stor Cooling Booster provides two key benefits. First, it improves the air conditioner's efficiency and cooling capacity on hot days. Efficiency improvement can approach 25% for rooftop units that operate significantly hotter than the ambient air temperature. The hotter the day, the greater the efficiency improvement. Second, it reduces peak power demand because its extra cooling capacity allows a smaller unit to replace a larger one.

The TCB is effective when the ambient temperature exceeds 85°F. During these times, it cools the condensed Freon below ambient temperature to improve system efficiency. The TCB uses a salt hydrate as a thermal energy storage medium to absorb and release energy by melting and freezing. The salt hydrate melts during the day as it cools hot Freon flowing from the air conditioner's condenser. It refreezes at night when the air temperature drops below its freezing temperature. The melt/freeze temperature of the selected hydrate is 87° F, but other media can be used to extend the temperature range from 70 F to 95 F. A schematic illustrating typical operation during a 100°F day is shown in Figure 1-1.

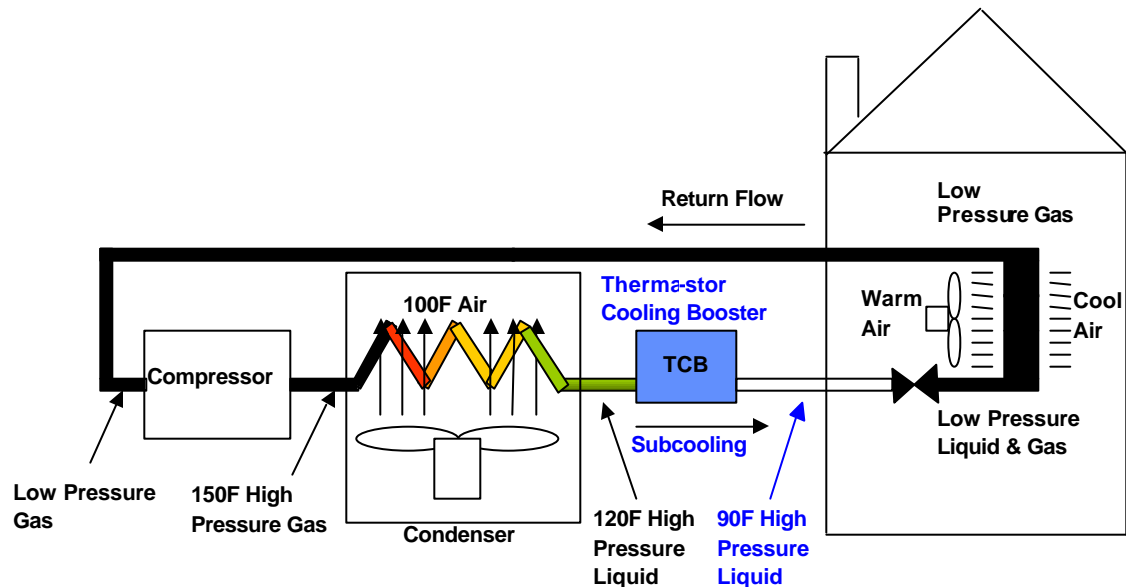


Figure 1-1. Schematic Illustrating Operation of the Therma-stor Cooling Booster

This product is unique because it uses a thermal energy storage medium to cool the condensed Freon on the hot (condenser) side of an air conditioner. Other systems that cool the condensed Freon, such as a mini-cooling tower, are complex, have high first costs (product cost plus installation costs) and high maintenance costs. The high thermal energy storage capacity of the salt hydrate allows a design that is highly reliable, maintenance-free, and compact. Also, the

TCB is constructed with inexpensive materials and fabrication methods, making it economically feasible. These factors combine to make the TCB an innovative and practical device.

Progress Made Subsequent to the Initial Report

The TCB has been developed and refined over the last four years. Each iteration resolved technical challenges and improved the design. Two major technical challenges that have been resolved are effective heat exchange with and long-term performance of the salt hydrate. The TCB is now in the I&I Category 2, Stage 3 Development stage.

A residential field test in the summers of 2001 and 2002 in Boulder, Colorado proved that the TCB increases efficiency and cooling capacity. In the test, a two year old 10 SEER 4-ton air conditioner was replaced with a new 10 SEER 3-ton air conditioner incorporating the Thermo-stor Cooling Booster. The extra cooling provided by the TCB enabled the 3-ton unit to cool the 2450 square foot residence to a low of 73°F with an outdoor temperature of 95°F. This was two degrees warmer than the 4-ton unit could achieve. The cooling demand, however, was easily met when the thermostat was set at 75F. Energy measurements showed electric current demand dropped from 19.5 amps to 14.5 amps at 230 VAC, thus reducing peak demand by 1.15 kW. The TCB boosted the cooling well into the evening, at which time extra cooling was no longer needed. The fan consumed approximately 1.5 kWh each night to reject heat from the TCB and prepare it for the next day. Figure 1-2 shows the 4-ton unit and the 3-ton unit with the TCB. Figure 1-3 shows test data of the 3-ton unit with and without the TCB. Note that when the TCB is on, the Freon temperature at the TCB outlet (blue line) is much lower than when the TCB is off. This colder Freon produces more cooling at the expansion valve and evaporator in the house.

Although this test successfully replaced a 4-ton unit with a 3-ton unit, the proposed program will take a more conservative approach. New units having ½ ton less rated cooling capacity than those typically required will be installed.



Figure 1-2. Original 4-ton unit and 3-ton unit with TCB

Comparison Test with & without TCB - 8/6/01

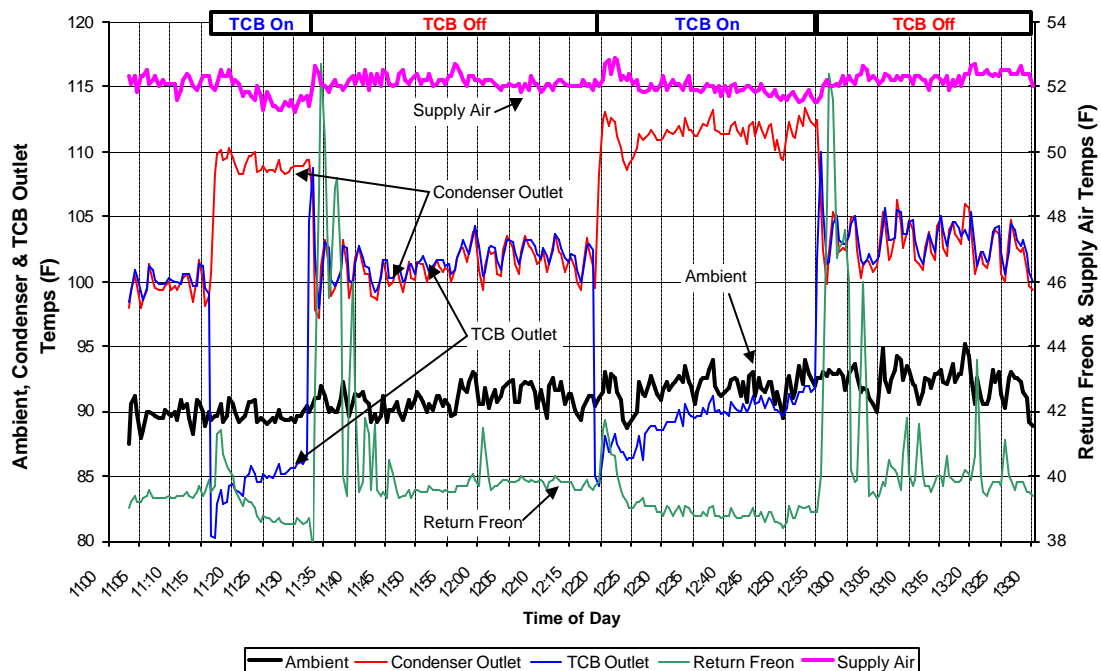


Figure 1-3. Test Data Showing Increased Cooling from TCB

Questions and Answers

The following material provides answers to questions we have received from interested outside parties.

Q: Could you give us further description on the number and type of lab or field tests that have been run on latest or similar configurations in the last 2-3 years, such as info on the test locations, length of testing and type of data collected (temperatures, power, pressures?). Have the latest tests been generally successful?

A: The latest configuration has been in test by Redstone at a residence for the last 2 years. We removed the original 4-ton unit and replaced it with a 3-ton unit augmented with the TCB. We also changed the flowrate (orifice) in the evaporator to match the 3-ton condensing unit. The purpose of the test was two fold: to measure the performance impacts the TCB on the air conditioner, and to monitor the long-term performance of the salt mixture. We measured several temperatures with thermocouples and made intermittent measurements of power and operating pressures. The measured performance was generally in line with our expectations, but there were a couple of surprises. The first surprise was that the condenser outlet temperature ran about 10F warmer than the ambient air, while we were expecting a 15F difference. We found that the 3-ton condensing unit had the same condenser coils as the 3.5-ton unit, so the condenser in the 3-ton unit was oversized, which resulted in a lower condenser temperature. Increasing the size of the condenser coils is a standard approach to achieving higher efficiency. The second surprise was that when the TCB was active and cooling the Freon down to near the TCB temperature, the condenser outlet temperature increased and the condenser pressure decreased. After reviewing the data, we concluded that the condenser was operating at saturated conditions (no subcooling) because the measured pressure matched the condenser outlet temperature. This may have been caused by the unit being undercharged, but we haven't investigated this any further to test the hypothesis. The temperature data was in line with

expectations. The Freon was cooled to within a couple of degrees of the TCB temperature during the day, indicating that the heat exchanger worked quite well to distribute the heat evenly throughout the salt. We found that the TCB was often well below 90F early in the morning even on the hottest days, so when it first kicked on (when the ambient temperature exceeded 85F), it subcooled the Freon to the low 80's. This situation is probably unique to arid climates where the nighttime temperature drops into the low 70's. The temperature data also showed the supply air temperature dropped when the TCB was active. This indicates extra cooling capacity, but we could only estimate the amount based on air flow, heat capacity and humidity. The salt has performed well during the whole test. Our major performance indicators are TCB outlet temperature and duration of effective cooling. We haven't detected any change in performance between last summer and the summer before, but this certainly doesn't exclude the possibility that some degradation has occurred. In 2003 we will disassemble and inspect the unit before the summer cooling season starts. We have been pleased with the overall performance of the device. We've identified some changes we will make to the hardware for production units, but it generally met our expectations. We have two hurdles to overcome to make the product commercially successful: we need more test data to better show how much energy it will save, and we need to reduce the payback from the current projection of 5 years to 3 years, and we're working on both.

Q: In an earlier report, you were discussing how to deal with various issues of the PCM such as incongruent melting and supercooling. In the latest write up you sent, you discuss using salt tubes 1 inch in diameter to deal with the incongruent melting/settling issue. You noted no sign of performance degradation over 90 cycles in the lab test. Could you estimate how many freeze/thaw cycles the tubes have seen in the field tests and if any performance degradation has been observed there? Have there been any further lab tests?

A: The salt has seen approximately 200 freeze-thaw cycles over the last two years. Most of those have been partial thaws. We haven't done any more freeze-thaw lab tests. The approach we use to stabilize the salt is described in a 1991 Korean paper and the author said they tested the salt for 300 cycles with no degradation, so we figured if we didn't see anything for 90 cycles we're probably good for at least 300. But we certainly intend to conduct more testing prior to mass-producing these units. In our discussion with potential investors, having to replace the salt every 5 years or so was potentially a good thing because it provides a revenue stream for maintenance contractors. We disagree with this view and think it should be maintenance free for the life of the a/c. We'll see who's view wins.

Q: Are you still using 3% borax to minimize supercooling effects?

A: Yes, and it works well.

Q: Does the salt solution no longer contain the disodium phosphate that was 35% of the mixture in the CEC report?

A: Our field test model has sodium sulphate decahydrate only. We tested units with the disodium phosphate in San Diego with bad results so we switched back to NaSO₄-10H₂O. (The salt in the units tested in San Diego was improperly mixed and did not refreeze properly.)

Q: Do you have an engineering performance model of the current configuration?

A: We have a system model to predict the performance of the TCB integrated with an air conditioner. We have had an engineering model under test for two summers.

Q: Have there been any independent tests of your technology such as by PG&E or others?

A: We did a test with an earlier version with funding from SDG&E. We tested three units in the San Diego area. Unfortunately, the Disodium phosphate salt mixture didn't perform and the units offered no savings (as you would expect).

Q: We noticed in the latest configuration that the fan in the TCBA unit now can run during the day to assist in obtaining further subcooling. Does it run all the time that the TCB is discharging? Is the 162W level you mentioned for both the fan and the pump? How much power do each draw separately?

A: Yes, the fan runs whenever the TCH is discharging. In the integrated unit, this has no impact (except for extra pressure loss) because the fan runs whenever the a/c operates. In a 5-ton stand alone unit, the fan will have a 1/6 hp (125W) motor and the pump will be 1/20 hp (37W).